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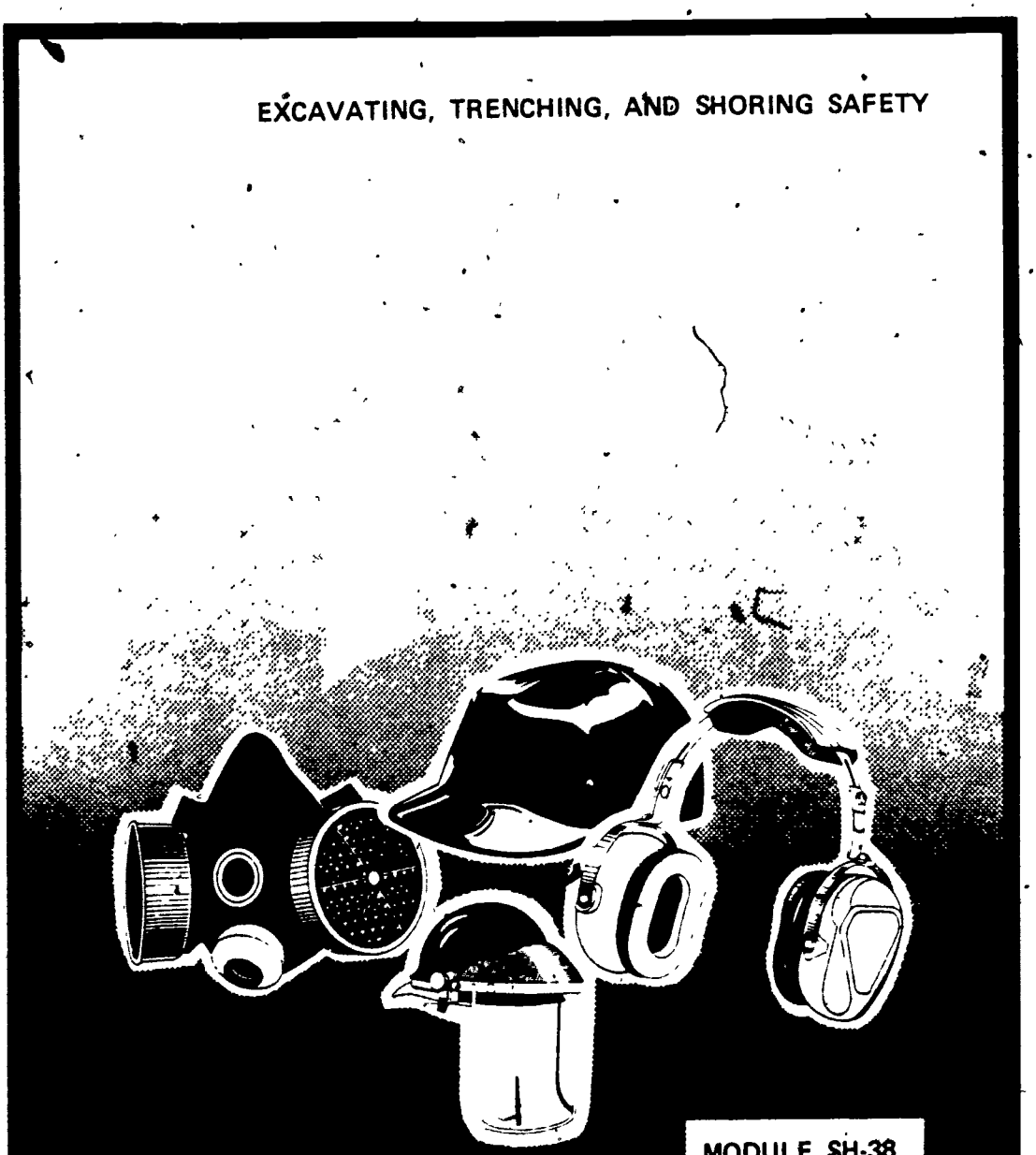
ABSTRACT

This student module on excavating, trenching, and shoring safety is one of 50 modules concerned with job safety and health. This module outlines the hazards of trenching and shoring and the procedures and equipment that should be employed to prevent cave-ins and other trenching and shoring accidents. Following the introduction, 10 objectives (each keyed to a page in the text) the student is expected to accomplish are listed (e.g., Discuss the "angle of repose"). Then each objective is taught in detail, sometimes accompanied by illustrations. Learning activities are included. A list of references and answers to learning activities complete the module. (CT)

# SAFETY AND HEALTH



## EXCAVATING, TRENCHING, AND SHORING SAFETY



MODULE SH-38



ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

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## INTRODUCTION

Excavating, or digging into the earth, is one of the most common industrial and construction processes, but this apparently simple task can be deadly if proper safety precautions are not taken. Two main hazards are associated with excavation: unguarded contact with utility lines and cave-ins, or earth slides, in which workers can be pinned or smothered. Both kinds of hazards can be safeguarded through adequate pre-excavation study and careful trenching and shoring procedures. Trenching and shoring regulations developed by the Occupational Safety and Health Administration are designed to guide in the planning of these operations. Where the regulations are routinely enforced, relatively few accidents need ever occur.

This module outlines the hazards of trenching and shoring and the procedures and equipment that should be employed to prevent cave-ins and other trenching and shoring accidents.

## OBJECTIVES

Upon completion of this module, the student should be able to:

1. Define the terms excavation, trenching, and shoring. (Page 3)
2. Discuss the use of mechanical power equipment in trenching and shoring. (Page 4)
3. Name three types of atmospheric contamination that may be present in trenches. (Page 6)
4. List five conditions that could lead to hazards in excavation and trenching. (Page 8)
5. Explain the need for pre-excavation study. (Page 10).
6. Discuss the "angle of repose." (Page 11)
7. Describe methods and materials used in shoring. (Page 13)
8. Describe the procedures for installing and removing shoring. (Page 16)
9. Discuss inspections of shoring. (Page 18)
10. Discuss the need for quick exits. (Page 19)

**OBJECTIVE 1:** Define the terms excavation, trenching, and shoring.

Figure 1. Workers in a trench.

An excavation is any man-made hole created by the digging up and removal of soil. The work may be done by power equipment or, at certain stages, with hand tools.

A trench is a narrow excavation that is deeper than it is wide, but never wider than 15 feet. (See Figure 1.)

Shoring is the primary method of stabilizing earth walls that have become loosened by excavation. Shoring is a framework of wood, metal, or both, erected to protect against cave-ins during the progress of the digging.

Excavations are prerequisites for many types of construction: the foundations and underpinnings of buildings, underground sewage and gas lines, or footings for any structure requiring massive support.

## ACTIVITY 1:*

1. Fill in the blanks:
   a. A trench is no wider than _____.
   b. Shoring may be constructed of _____, _____, or _____.
   c. An _____ is created by the digging up and removal of soil.
   d. Shoring protects against _____.
2. Name three types of construction for which excavation is necessary.
   a. _____
   b. _____
   c. _____

**OBJECTIVE 2:** Discuss the use of mechanical power equipment in trenching and shoring.

A large-scale excavation requires heavy equipment such as power shovels, draglines, caterpillars, derricks, cranes, backhoes, hoists, or drilling rigs. The operating area of such machines must be cleared of employees who might sustain injury from contact with the machinery itself or from spillage of earth set in motion by the machinery.

Vibration from heavy equipment operation, especially when equipment is operated close to the edge of an excavation, can make relatively stable earth become loose to the point of cave-in. The weight of this equipment, when it is stored too close to the edge of a trench, can impose stress on trench walls even if machinery is not in operation.

Every piece of heavy equipment used in trenching and shoring should be equipped with the basic safety and operating equipment required by OSHA

*Answers to Activities begin on page 20.

standards as set forth in Part 1926. Adequate braking systems, lighting, audible warning devices (such as a horn), windshield wipers, rollover protective structures (ROPS) for operator protection, seat belts, and safety latches or locks for dumping mechanisms are some of the safety features that regulations require. Heavy equipment operators should be well trained and meet requirements of the state licensing agency (if there is one) or company or union certification programs.

Operators should make sure that heavy equiment is fully lowered or blocked when not in use, with controls in neutral position, motors stopped, and brakes set.

All machines used in excavating must be well maintained and kept in safe repair for use when needed. Cranes and derricks are required to be inspected constantly, before and during use, by a competent person appointed by the employer. A thorough annual inspection of the hoisting machinery must be made by a competent person, or by a government or private agency recognized by the U.S. Department of Labor.

Hand-held power tools must be equipped with an instant on-off control and may have a lock "on" control if machine can be turned "off" by a single motion of the same fingers used for turning it on.

When excavation is being conducted by hand power tools, workers should beware of hitting underground utilities, such as gas, sewer, telephone, water, or electric lines. The grounding of powered tools can protect workers from electric shock in the event of sudden contact with a buried power line. In the case of a pneumatic tool that has a conductive hose, this can be accomplished by attaching the air hose to a driven ground.

**ACTIVITY 2:**

1. Explain two ways that heavy machinery can contribute to cave-ins.
   a. _____
   b. _____
2. Name six safety features required on heavy equipment.
   a. _____
   b. _____
   c. _____

d. _____

e. _____

f. _____

**OBJECTIVE 3:** Name three types of atmospheric contamination that may be present in trenches.

In locations where oxygen deficiency or gaseous conditions are possible, air in the excavation should be tested. At least three different types of atmospheric hazards may be life threatening: oxygen deficiency, toxic (poisonous) gases, or flammable gases.

When flammable gases are present, adequate ventilation must be provided or sources of ignition must be eliminated. Sources of ignition include open flames, electrical sparks, heated surfaces, or friction, to name a few. Smoking should not be allowed in or near trenches that are known to be or suspected of being contaminated. No open-flame device such as solder pot furnaces or welding equipment is permitted in or near trenches (or manholes or tunnels) when tests have indicated the presence of flammable gases or liquids.

Toxic gases may necessitate the use of respirators that filter out toxic fumes or gases (cartridge respirators) or ones that supply breathing air. Air-supplied respirators may be necessary, also, where oxygen loads are too low to sustain life. Sometimes the problems of toxic fumes and oxygen deficiency may be solved through the use of ventilation devices such as blowers or suction fans.

Where adverse atmospheric conditions may exist or develop in an excavation, emergency rescue equipment should be present and attended by personnel. Such equipment would include breathing apparatus, a safety harness and line, and a basket stretcher.

Sometimes dust conditions are a hazard in trenches. Dust conditions must be minimized through the use of water, salt, calcium chloride, oil, or other means.

FIRE EXTINGUISHERS

A portable fire extinguisher, rated 2A, must be provided for each 3,000 square feet of the trench work area. Travel distance from any point of the protected area to the nearest extinguisher cannot exceed 200 feet. A 1/2-inch diameter garden type hose, mounted on a rack or reel, can be substituted for a 2A-rated fire extinguisher if it is capable of discharging five gallons per minute with a minimum stream range of 30 feet horizontally.

A fire extinguisher rated no less than 10B must be provided within 50 feet of wherever more than five gallons of flammable/combustible liquids, or five pounds of flammable gas, are being used on the job site.

Portable fire extinguishers must undergo periodic inspection and maintenance in accordance with Maintenance and Use of Portable Fire Extinguishers, NFPA (National Fire Protection Association) Standard No. 10A-1970.

**ACTIVITY 3:**

1. Name three types of hazardous atmospheres.
   a. _____
   b. _____
   c. _____
2. Name two means of controlling toxic gases in trenches.
   a. _____
   b. _____
3. In which of the following hazardous atmospheres would removal of all ignition sources be an essential precaution?
   a. Oxygen-deficient atmospheres.
   b. Flammable gas atmospheres.

**OBJECTIVE 4:** List five conditions that could lead to hazards in excavation and trenching.

Among the many factors involved in planning a safe, effective excavation are:

- Soil structure.
- Weather conditions.
- Overhead and underground utilities.
- Superimposed loads.
- Vibrations.

The soil structure must be thoroughly analyzed. The more clay in the soil, the more it will tend to stick together; thus it is less likely to slide when excavated. If soil is loose and sandy with areas that have been backfilled, the excavation will be relatively unstable and in need of strong support. The opposite extreme is hard rock, but even hard rock may have faults or cracks that make it unstable when cut. The consistency of even very cohesive soil can be changed by the number-one enemy of trenching operations: water. Whether from a surface supply, the water table, or moisture content in the ground, water can reduce the stability of the soil.

Water - from the surface, water table, or moisture content in the ground - reduces or undermines the compactness of the soil and the stability of the trench sides. Rain or snow can also make the banks of an excavation collapse, or fill a trench with water. Diversion ditches or dikes can prevent water from entering an excavation; a good drainage system, such as a pump, will keep rain or ground water from collecting in the bottom of a trench.

Temperature changes may make soil unstable. Frozen soil is usually stable, but the consistency of the unfrozen soil below the frost line will be less cohesive. Freezing can cause expansion of soil; in turn, that may increase the pressure against the sides of the trench walls. Thawing can cause mud slides and cave-ins, or result in heavy equipment slipping into the trench. Even dry soil can present problems since it tends to crack.

Overhead and underground utilities have been mentioned in relation to power tools; all utilities represent potential excavating hazards. Before excavation begins, the contractor must find out from utility companies precisely where such lines are located, and make plans for avoiding them. Accidental contact with electric lines can cause burns or electrocution. When possible, overhead power lines should be turned off before work begins. Equipment with booms must maintain a 10-foot minimum clearance between the boom and any overhead lines.

Damaged gas or sewer lines may leak toxic gases where workers are present, thereby creating a need for respiratory protection. Fires and explosions can result from leaking gas lines, also. Some utilities can be shut off while work is in progess; otherwise, care should be taken to work around them.

Wherever underground utility lines exist, one can assume that the ground has been excavated previously, leaving the earth less stable than if it had been undisturbed.

Superimposed loads (loads laid over the trenching site) may include heavy items such as pipes or timbers, which increase pressure on the excavation walls. These loads should be kept as far away from the edge of the excavation as possible, at least two feet.

Spoil (earth dug out of the excavation and placed on the surface) can also put a strain on the system. OSHA requires that spoil be stored (banked) at least two feet from the edge of the excavation, where it should be effectively barricaded or retained.

Vibrations caused by vehicular traffic or by heavy machinery in operation can be literally earth shaking. If workers must dig under such conditions, every possible measure should be taken to prevent a cave-in.

**ACTIVITY 4:**

1. List three weather conditions that can affect the stability of a trench.

   a. _____

   b. _____

   c. _____

2. Name two sources of vibration on an excavation site.

a. _____

b. _____

**OBJECTIVE 5:** Explain the need for a pre-excavation study.

Any professional contractor will thoroughly inspect a prospective excavation site with a variety of considerations in mind: the soil, utility lines, traffic conditions, the weather, the water table, and surrounding existing structures.

Circumstances of the site can be determined by observation, test borings for soil analysis, consultations with local officials. Utility companies will help locate sewer, water, fuel, and electric lines so that accidental damage can be avoided. Utility officials should be informed of proposed work 24 hours before digging begins. The contractor is responsible for covering over any underground installations that were exposed during excavation.

At the present time, there is no nationwide policy on the shutdown of power lines during trenching operations. In some states, when an excavation is considered to be too close to a utility installation, the power company will choose one of these two options: charge the contractor a fee for digging on that spot, or require that the contractor move to another location. Localities may have differing requirements, also.

After deciding upon a site, the contractor should figure into the bid the amount, kinds, and costs of safety equipment appropriate for that particular job. Excavation or trench cave-ins are responsible for a growing number of employee injuries and fatalities. The price of cave-ins is too high for any unnecessary risks to be taken.

No contractor can afford employee casualties, the costs or property damage, or increased insurance and compensation payments. The wise

contractor will make job safety part of his bid - to protect employees, to protect the public, and to protect the investment.

**ACTIVITY 5:**

List five factors that should be included in the pre-excavation study:

1. _____
2. _____
3. _____
4. _____
5. _____

**OBJECTIVE 6:** Discuss the "angle of repose."

An excellent way to protect workers in trenches or excavations is to slope the sides of the cut to the proper angle of repose - the angle at which the earth will lie still without moving. This angle will vary from project to project according to the type of soil involved, the vibration from nearby equipment, the weight of structures in the vicinity, the proposed depth of the cut, and the potential weather conditions.

The most important factor in determining a correct angle is the stability of the soil in terms of composition and cohesion. Looser, less cohesive soils, for instance, require a flatter angle than solid rock or shale. For these solid materials, as well as for cemented sand and gravel, the angle of repose is straight up and down, or vertical (90 degrees).

For compacted, angular gravels, the approximate angle should be one to two. That is, for every two feet in height, the angle should extend one foot across. Expressed in degrees as angles are generally measured, this angle would be 63°26'. Recommended slope for average soils is one to one (45°). Compacted sharp sand requires an angle of three to two (38°41'), while well-rounded loose sand must be flattened to two to one (26°34'). Figure 2 illustrates what is meant by angle of repose.

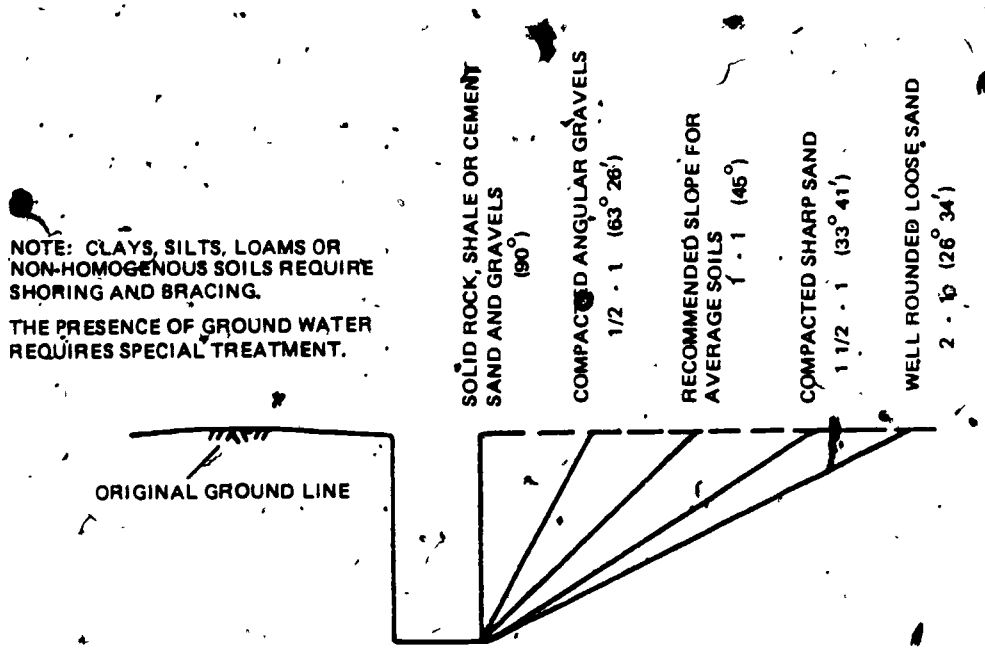


Figure 2. Approximate angle of repose for sloping of side of excavations.

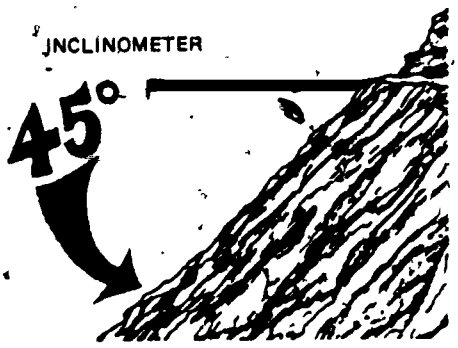


Figure 3. Inclinometer at slope.

Whatever the angle, it must be flattened for an excavation containing excess water, silty materials or loose boulders, and whenever erosion or deep frosts occur.

The untrained eye can only estimate the measurement of a given angle. An inclinometer should be used in deciding angle. This device measures the angle in degrees (see Figure 3). If there is doubt, it is best to overcompensate and make the angle somewhat flatter than called for by the instrument.

**ACTIVITY 6:**

Define "angle of repose." _____

_____

_____

**OBJECTIVE 7:** Describe the materials and methods used in shoring.

The greatest danger associated with excavation is the possibility of cave-ins or earth slides. Either mishap can pin down and possibly suffocate a worker.

To prevent such tragedies, OSHA requires that all excavations over five feet deep be sloped, shored, sheeted, braced, or by any one or combination of these methods be supported. If the soil is unstable, excavations of less than five feet deep must also have support. This ruling is for the protection of employees who may be endangered while they are actively engaged in shoring, as well as for those who are working in a trench for other reasons.

Excavations are supported by means of sloping (piling the spoils at a stable angle), bracing (horizontal members bearing against uprights), sheeting (a solid barrier against the excavation's walls), shoring (a framework of wood, metal or combination), and cribbing (a temporary means of supporting trench walls with scrap lumber). These methods can be used in combination - or in some cases, one method will suffice - to support excavation sites and prevent cave-ins.

Materials used in the support of excavations (planks, laths, timbers, various metals) must be of top quality and in serviceable condition. Supporting timbers must be of serviceable lumber, without large or loose knots, and cut to the proper dimensions.

Shoring materials consist of wood planks (for uprights and in some cases, brackets), and of metal components (as in trench jacks). Stringers, also known as waters, are horizontal timbers which support the uprights (Figure 4).

Sheeting is a solid barrier of timber, concrete, or sheet piles that is erected against the walls of an excavation. Its purpose is to resist the lateral pressure of water and loose soil. Sheeting should extend above the surface level to keep the spoil bank from sliding back into the excavation.

At times the workers will have to cope with an unstable excavation bottom: below the water line, for example. In this case, metal or concrete

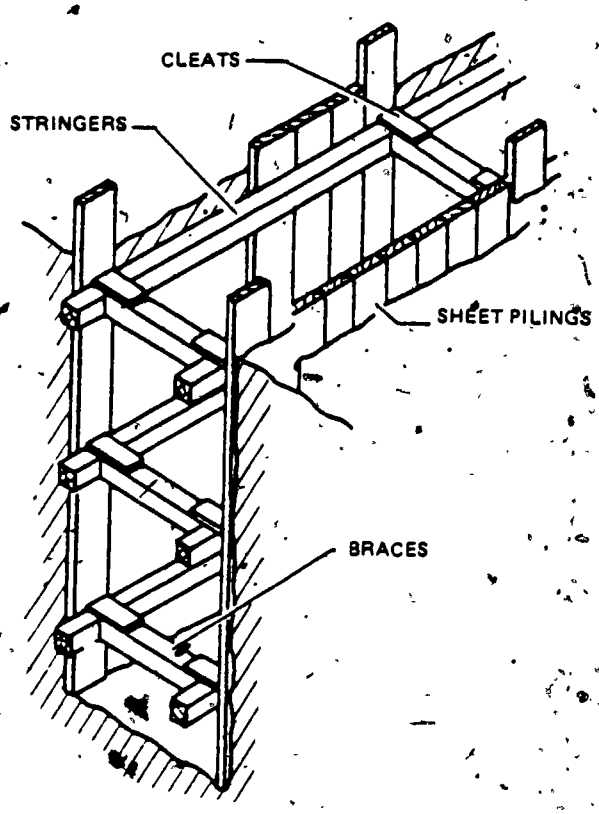


Figure 4. Shoring components.

sheeting must be driven below the bottom of the excavation to augment the stability of the soil, as shown in Figure 5. Timber shoring and sheeting does not usually remain in the excavation long enough to deteriorate.

OSHA requires that diversion dikes and ditches be dug to prevent surface water from entering an excavation and to provide adequate drainage of the area adjacent to the excavation.

Water causes erosion and softening of the soil, and should never be allowed to accumulate in an excavation.

Weather can play havoc with the best support systems. Large excavations are especially vulnerable to changing weather conditions because they often remain open for long time spans. A heavy rain will drastically increase pressure on shoring materials, which may then give way to cave-ins. When attempting to support such excavations, it is wise to take a long-range view and provide for a variety of weather contingencies. In extreme circumstances, cover the excavation walls with plastic sheeting, or use a moisture-limiting chemical spray on the spoil-bank. If water collects in the bottom of the excavation, the angle of repose can be flattened.

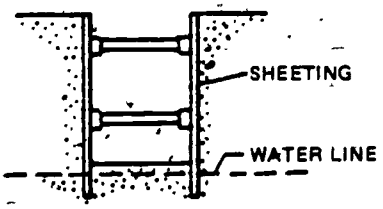


Figure 5. Sheeting driven below bottom line of water line.

After each major change in the weather that could jeopardize a shoring system, the excavation must be inspected for damage.

The entire shoring system must be solid and resistant to rotting. With any give or play, it could weaken under pressure. Therefore, shoring materials must always be of dependable quality.

Reinforcement of shoring is required in special cases, such as with a superimposed load. If a heavy load must be adjacent to an excavation, the walls of the excavation will need additional support. It may also be necessary to change the pressure of a heavy load - pile drivers and cranes, for example, can be mounted on wooden mats or heavy planking to distribute the weight over a greater area.

Constant vibration (sudden shock from passing vehicles, railways, jack hammers) can contribute to cave-in by weakening the soil. Even machines operated in nearby buildings can endanger the shoring system. In such cases, stronger support may be the only answer.

When it is necessary to shore the sides of an excavation that is adjacent to a previously backfilled excavation, every care should be taken to prevent the loose fill from sliding. This is particularly important when the original fill level is less than the depth of the excavation.

Digging below the level of the footing of a foundation or retaining wall is unsafe unless:

- The wall is well underpinned.
- The adjacent walls are stable.
- The material being excavated is hard rock.

**ACTIVITY 7:**

1. Name two conditions in which OSHA requires that diversion dikes and ditches be dug:
   a. _____
   b. _____
2. List two actions that may be taken in extremely wet weather conditions.
   a. _____
   b. _____

**OBJECTIVE 8:** Describe the procedures for installing and removing shoring.

Figure 6. Dangerous overhang.

Ideally, shoring should take place as soon as possible after the excavation is dry. An unshored trench is risky because the earth walls can slough away, leaving a dangerous overhang as shown in Figure 6.

Shoring is always installed from the top down and removed from the bottom up. During installation, great pains must be taken to place the trench jacks (or cross beams) in true horizontal position between the uprights and to space them vertically at even intervals as shown in Figure 7. Once the system is in place, there should be no space between shoring and walls. Soil leaks must be promptly packed with earth, for if support is vulnerable at any point, the system may gradually give way.

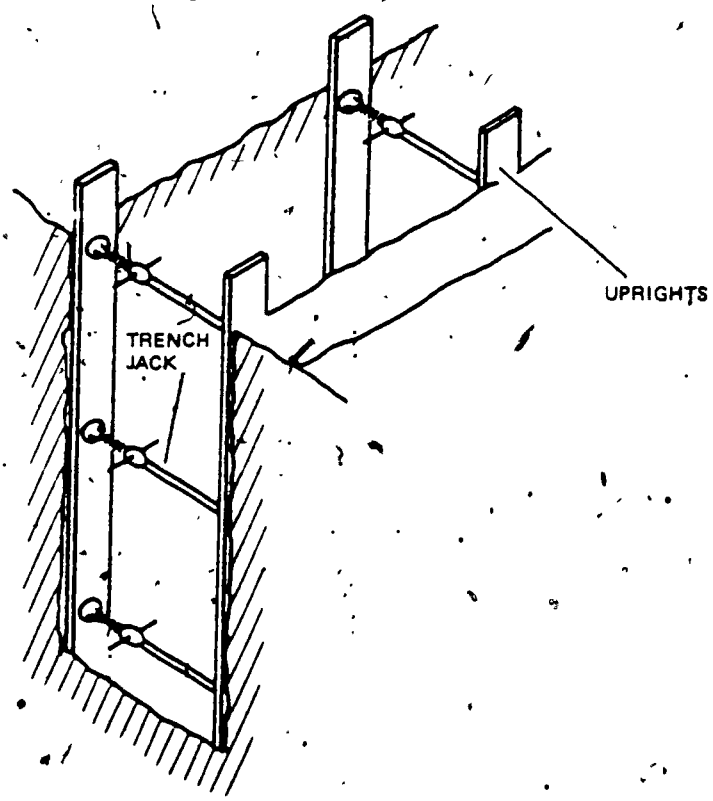


Figure 7. Trench jacks in true horiontal position.

When all construction materials required are properly placed in the excavation, backfilling and removal of trench supports should proceed simultaneously - from the bottom up. Trench jacks and brakes must be released very slowly and cautiously, for the safety of both trench and workers.

If the soil is

unstable, the jacks/braces are pulled out from above, with ropes, after the employees have left the trench. Only then should the shoring be completely removed, preferably by equipment rather than by hand.

The trench shield (or sliding trench shield) is a variation on shoring techniques already described. It is composed of steel plates and bracing that are welded or bolted together and it can be moved along as digging progresses, carrying workers inside, as shown in Figure 8.

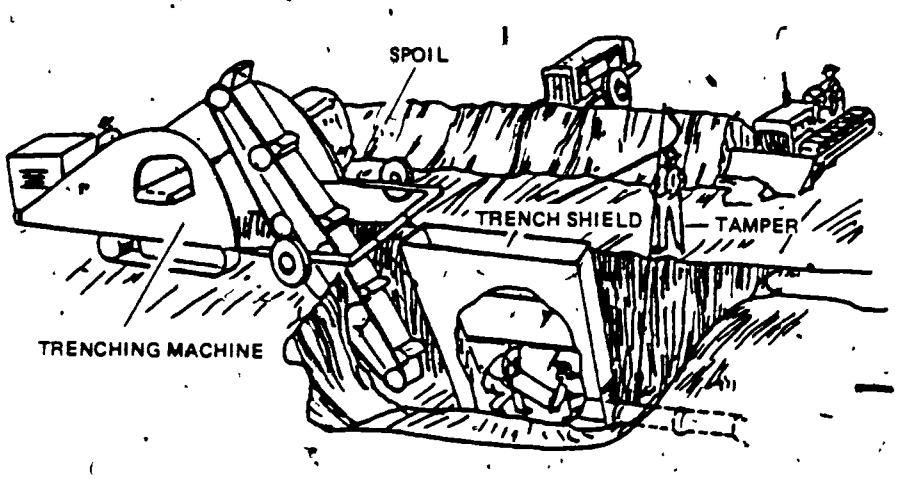


Figure 8. Trench shield.

The shield supports the trench walls from the surface to the bottom, but usually does not fit as snugly as sheeting or shoring is required to do. A trench shield is not intended to replace conventional shoring; it is primarily a device for added safety and convenience. Even if the walls collapse and fall all around the shield, the workers inside it will be protected.

The sliding trench shield is also effective in situations where other systems are not feasible or adequate. It may be used in extremely unstable ground, for instance, or on jobs of very short duration.

**ACTIVITY 8:**

1. Explain the correct methods of backfilling and removal of trench supports.

2. Mark the statement True or False.

____ a. A trench shield is intended to replace conventional shoring.

____ b. If the walls of a trench collapse, workers inside the trench shield will be protected.

**OBJECTIVE 9:** Discuss inspections of shoring.

All types of shoring, plus the excavation itself, must be inspected daily. During the time span of the work, several conditions can occur that would endanger the support system:

- Timber or ground may dry out and contract, thereby loosening the shoring.
- The earth may absorb moisture and swell, thus displacing the shoring.
- Some components of the system may be displaced or damaged by materials lowered into the trench.
- Shoring itself, or part of its support, may rot.

Excavations must be inspected daily by someone experienced in recognizing trenching hazards. In addition, the inspector must make a study immediately following every rainstorm, or after a change in conditions that might increase the possibility of disaster.

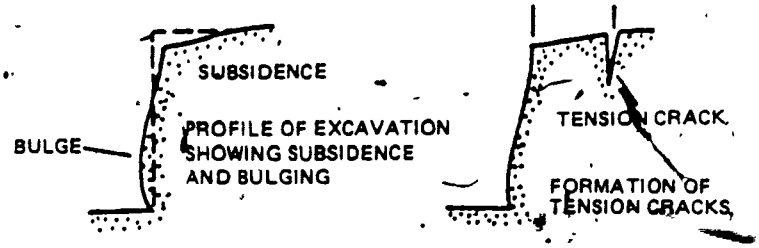


Figure 9. Diagram of subsidence and tension cracks.

If dangerous ground movements are detected (see Figure 9) such as subsidence (when the earth of a wall gradually "subsides"), or tension cracks (when there is too much stress upon a wall), ALL

WORK MUST BE STOPPED until the problem has been analyzed and corrected.

**ACTIVITY 9:**

Give three reasons for regular inspection of excavations.

1. _____
2. _____
3. _____

**OBJECTIVE 10:** Discuss the need for quick exits.

In case of emergency, workers must be able to get out of the trench as quickly as possible. Therefore, OSHA requires that trenches of four feet deep or more must be provided with a means of immediate exit. Ladders (or steps) are placed in every such excavation at intervals of 25 feet along the walls (see Figure 10). The side rails of the ladders must extend at least three feet above the landing surface to facilitate a speedy escape. Every ladder provided must be functionally strong and secured at the top of the trench.

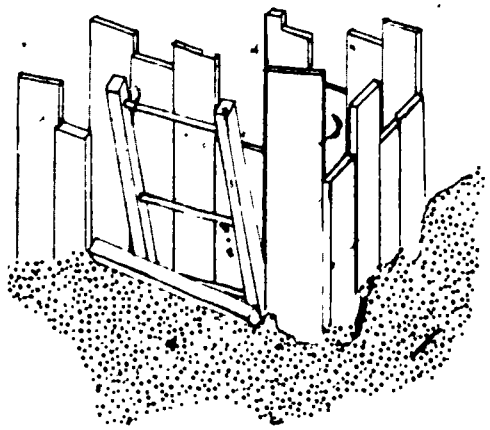

Figure 10. Exit ladder.

The design of ladders used in trenching and shoring must be in accordance with American National Standards Institute A14.1-1968, Safety Code for Portable Wood Ladders. Portable metal ladders must be of equivalent strength to wood and conform to American National Institute, A14.2-1956, Safety Code for Portable Metal Ladders.

Ladders should be firmly based on level ground with the areas around top and bottom kept clear. The pitch must be such that the horizontal distance from the top support to the foot of the ladder is about 1/4 the working length of the ladder - a comfortable angle.

"Job-made" ladders are constructed for their intended use, as in trenching. If they are to provide the only means of access or exist from a work area for 25 or more employees, or in case of simultaneous two-way traffic, the ladders must be double-cleated for additional protection of the workers. As a further safety measure, the ladders are secured at the top of the trench by wires or ropes which are attached to stakes, or to any appropriate supportive objects protruding above the ground.

**ACTIVITY 10:**

Describe three safety requirements for ladders used in trenches.

1. _____
2. _____
3. _____

## REFERENCES


U.S. Department of Labor. Occupational Safety and Health Regulations for Construction. 29 CFR 1926, (1980).

U.S. Department of Labor. OSHA Pamphlet 2226.


## ANSWERS TO ACTIVITIES

ACTIVITY 1

1. a. 15 feet.
   b. Wood, metal, or both.
   c. Excavation.
   d. Cave-ins.
2. a. Foundations and underpinnings.
   b. Underground sewage and gas lines.
   c. Footings for structure.

ACTIVITY 2

1. a. Vibration.
   b. Weight, when stored too close to the edge of the trench.

(Any six.)

2. a. Adequate braking sysems.
   b. Lighting.
   c. Audible warning devices.
   d. Windshield wipers.
   e. Rollover protective structures.
   f. Seat belts.
   g. Safety latches or locks for dumping mechanisms.

ACTIVITY 3

1. a. Oxygen deficiency.
   b. Toxic gases.
   c. Flammable gases.
2. a. Ventilation.
   b. Respiratory protective equipment.
3. b.

ACTIVITY 4

(Any three.)

1. a. Rain.
   b. Snow.
   c. Freezing.
   d. Thawing.
   e. Extreme heat and dryness.
2. a. Nearby traffic.
   b. Heavy equipment operation.

ACTIVITY 5

(Any five.)

1. Utilities location.
2. Soil conditions.
3. Traffic.
4. Weather.

5. Water table.
6. Surrounding structures.

ACTIVITY 6

The angle at which the earth will lie still without moving.

ACTIVITY 7

1. a. To prevent surface water from entering an excavation.
   b. To provide adequate drainage of the area adjacent to the excavation.
2. a. Cover excavation walls with plastic sheeting.
   b. Use a moisture-limiting chemical spray on the spoil bank.

ACTIVITY 8

1. Backfilling, and removal of trench supports are done from bottom up, simultaneously; release jacks and braces very slowly; if soil is unstable, trench is cleared and bracing is pulled out from above by ropes.

ACTIVITY 9

(Any three.)

1. Timber or soil may dry out and contract.
2. Soil may absorb moisture and swell.
3. Shoring itself may rot.
4. Shoring components may be damaged by materials lowered into the trench.

ACTIVITY 10

(Any three.)

1. Must be based on level ground.
2. Must be double-cleated when only means of exit for 25 or more workers.
3. Must be secured at top of trench.
4. Must be placed at sloping rather than vertical angle.